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**PICKERING NGS A
REACTOR VAULTS
LABORATORY TESTING OF
HIGH-DENSITY CONCRETE CORES**

Report No. 91-194-K

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ABSTRACT

Sections of concrete cores drilled from the Pickering NGS A reactor vaults were selected and shipped by Construction personnel to the Research Division laboratories. Specimens were prepared from the cores from Units 1 and 3 and tested in the laboratory to determine physical and thermal properties and the chemical composition of the concrete, and to provide information regarding any changes in these properties, which may have occurred due to the operating environment of the reactor. It was found that the physical properties of the concrete from the Unit 1 reactor vault differed significantly from those of the Unit 3 reactor vault. The thermal properties of the Unit 3 concrete generally varied from those obtained previously on other high-density concrete, although the thermal conductivity was similar to that of a concrete core from Pickering NGS A tested in 1989. Minor variation was noted in the properties of the concrete from various locations through the thickness of the wall, but it could not be determined whether this was due to the service environment of the reactor vault or was within the variability of the test procedure. It should be noted that the section of core from the inside face of the reactor vault, which would be expected to show the most significant effect of the service environment, was not received or was not suitable for testing in any of the cores received from Units 1 and 3. The chemical composition of a sample of high-density concrete was determined to assist in the analysis being performed by others on debris from the reactor vault.

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**PICKERING NGS A
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E.J. McColm

1.0 INTRODUCTION

Cores of high-density concrete were drilled from the Pickering NGS A reactor vaults as part of construction activities carried out for Units 1 to 4. From the cores, sections were selected and shipped by Construction personnel to the Research Division laboratories. At the request of Mr. C.M. Alexander of the Civil Engineering and Architecture Department, the Concrete Technology Section, Civil Research Department, undertook laboratory testing of the concrete cores. The purpose of the testing was to determine the physical and thermal properties and the chemical composition of the concrete, and if possible, to provide information regarding any changes in these properties, which may have occurred due to the operating environment of the reactor. This report summarizes the results of the laboratory testing of the concrete cores.

2.0 DESCRIPTION OF CORES

The drilling, selection and shipping of the cores was performed by Construction and Operations personnel. The Concrete Technology Section, Civil Research Department, received sections of cores drilled from each of the four Pickering NGS A reactor vaults. The test program reported here was carried out on the cores from Units 1 and 3. The cores from Units 2 and 4 are being stored for future testing, if required.

Two cores were received from each of Units 1 and 3. These cores were reportedly drilled horizontally from the high-density concrete plug in the south wall of the reactor vaults at Elevation 278.5'. The cores were identified as Core W from the west and Core E from the east of the plug. The wall at this location is 2.13 m thick. Cores 1W and 1E (1.83 and 2.13 m) were received from Unit 1 and Cores 3W and 3E (1.83 and 1.87 m) from Unit 3. The section of core closest to the interior of the reactor vault was only received in Core 1E. The cores had a diameter of either 119 or 144 mm. A description of the cores is given in the concrete core log in Appendix A.

As a result of the drilling procedure, Sections 1E5 to 1E8 from Unit 1 and Section 3E6 from Unit 3 were irregular in cross-section and could not be used for testing.

The concrete in the cores appeared to be in good condition. The distribution of the aggregates, which had a maximum nominal size of 15 mm, was classified as good. The core breaks appeared to be caused by drilling and occurred through the aggregate. Although the concrete was reported to be non-air-entrained, numerous entrapped voids (5 mm in size) were identified. An examination of the concrete identified the aggregate as ilmenite ore. White deposits, associated with fine cracks, were observed in the Unit 3 specimens after they had been immersed in water for approximately two months. These cracks appeared to be confined to the mortar and did not extend into the coarse aggregate. Sections of the cores from Unit 1 immersed in water for over three months did not develop similar cracks.

From the Concrete Inspectors Daily Reports, typical mix proportions used for this concrete are as follows:

Cement (LHP)*	590 lb/yd ³
Water	280 lb/yd ³
W/C Ratio	0.47
Fine Aggregate (Ilmenite)	2310 lb/yd ³
Coarse Aggregate (Ilmenite)	3220 lb/yd ³
Admixtures	
Pozzolith 83 (water reducer)	1.2 lb/yd ³

* The cement used was probably Low Heat Portland Cement

3.0 LABORATORY TESTING

Specimens were prepared from the cores and tested in the laboratory to determine the physical and thermal properties and chemical composition of the concrete. The results obtained from tests on specimens selected from various locations through the thickness of the wall were reviewed to determine whether or not any change in the properties of the concrete had occurred due to the operating environment of the reactor vault. The laboratory test results were also compared to the results of tests carried out during construction. The section of core closest to the inside face of the reactor vault was not received or was not suitable for testing. This section of core would be expected to show the most significant effect of the service environment of the reactor vault.

3.1 Physical Properties

The physical properties of the concrete evaluated and the test procedures followed are listed below. The results of these tests are given in Tables 1 and 2. Included in these tables are the results of tests conducted during construction as part of the quality assurance program.

Physical Properties

Density	- Civil Research Department Procedure
Absorption	- ASTM C 642
Ultrasonic Pulse Velocity	- ASTM C 597
Compressive Strength	- CAN/CSA-A23.2 - 14C
Modulus of Elasticity	- ASTM C 469

For Unit 1, the density of the test specimens ranged from 3863 to 3969 kg/m³ and averaged 3905 kg/m³, and for Unit 3, it ranged from 3532 to 3734 kg/m³ and averaged 3641 kg/m³. The density of selected concrete specimens prepared as part of the quality assurance program carried out during construction averaged 3795 and 3764 kg/m³ for Units 1 and 3, respectively. The density of the concrete from Unit 1 was significantly higher than that from Unit 3 and the values obtained during construction.

The absorption is a measure of the pore space in the concrete. For the concrete from the Unit 1 reactor vault, the absorption after immersion and the absorption after immersion and boiling were measured. The absorption values ranged from 2.8% to 3.1%. No significant difference in the values was noted after boiling the specimens for 5 hours. For the Unit 3 concrete, only the absorption after immersion was measured and ranged from 3.7% to 4.0%.

The ultrasonic pulse velocity ranged from 4440 to 4930 m/s and averaged 4700 m/s for the Unit 1 concrete, and ranged from 4150 to 4330 m/s with an average of 4240 m/s for the Unit 3 concrete. The measurements were made on the specimens prior to testing for compressive strength. Although the values between the two units vary, the pulse velocities are in the range generally associated with a good quality concrete.

The compressive strength and modulus of elasticity tests were carried out under two moisture conditions. For the moisture conditions reported here, it was assumed that 100% saturation was achieved when the saturated surface dry (SSD) specimen, immersed in water at 23°C, reached mass equilibrium over a 24-hour period (ie, change in mass <0.5% in a 24-hour period). The dry condition or 0% saturation was achieved when the specimen, in an oven at 100°C, had reached mass equilibrium over a 24-hour period (ie, change in mass <0.5% in a 24-hour period).

The cores from the Unit 1 reactor vault were tested at 50% saturation to represent the in situ moisture condition of the concrete. This moisture condition was selected based on tests conducted to determine the as-received moisture condition of the concrete (Table 1). The specimen closest to the outside surface of the reactor vault wall (Section 1W1) had a moisture condition of 26% saturation, while the remaining three specimens (Specimens 1W2, 1W4 and 1W5) were 46% saturated. It should be noted that the effect of the drilling water and the storage environment after drilling on the moisture condition could not be assessed, and the results reported here are therefore only estimates of the actual in situ moisture condition. The compressive strength and modulus specimens from the Unit 1 cores were conditioned by immersion in water for several days followed by drying at 50% relative humidity and 23°C until mass equilibrium was reached.

The cores from Unit 3 were tested in a SSD condition. This ensured a uniform moisture condition so that the results from different locations through the wall could be compared. These test results could also be compared to the results obtained during construction.

The compressive strength of the Unit 1 concrete, tested at 50% saturation, ranged from 47.1 to 55.3 MPa and averaged 50.6 MPa. This is significantly higher than the 28-day strength of 33.8 MPa obtained from selected specimens tested in a SSD condition during construction. It should be noted that the compressive strength of a test specimen is known to increase with drying of the specimen (ie, saturated specimens will be expected to have a lower strength than that of dry specimens). The compressive strength of the Unit 3 concrete, tested in a SSD condition (100% saturation), ranged from 28.8 to 35.2 MPa and averaged 32.8 MPa. These results were similar to the 28-day strength of 34.5 MPa obtained from selected cylinders tested as part of the quality assurance program carried out during construction.

The modulus of elasticity of the concrete from Unit 1, tested at 50% saturation, ranged from 50.4 to 53.7 GPa and averaged 51.9 GPa. For the Unit 3 concrete tested in a SSD condition, the modulus of elasticity ranged from 41.4 to 45.8 GPa and averaged 43.6 GPa. Tests carried out on high-density concrete, although different in composition and strength, as part of the concrete integrated cask (CIC) program produced modulus of elasticity values that ranged from 45.1 to 45.9 GPa/1/.

3.2 Thermal Properties

Specimens prepared from the cores drilled from the Unit 3 reactor vault were tested for thermal properties using the test procedures listed below. The results of the tests are given in Table 3.

Thermal Properties

Coefficient of Thermal Expansion	- CRD - C 39-81*
Thermal Diffusivity	- CRD - C 36-73*
Specific Heat	- CRD - C 124-73*
Thermal Conductivity	- CRD - C 44-63*
	- Transient Thermal Probe

* US Corps of Engineers test procedure

Most of the testing was carried out on specimens in a saturated surface dry (SSD) condition. This moisture condition was selected because it was relatively easy to achieve, simplified carrying out the tests and provided a uniform moisture condition so that the results from specimens obtained at different locations in the wall could be compared. The measurement of the thermal conductivity using the transient thermal probe was carried out at three moisture conditions.

The thermal properties evaluated as part of this program have been compared to values obtained previously on high-density concrete. In 1985, a program was undertaken to evaluate the thermal properties of a concrete for the Concrete Integrated Cask (CIC) program /1,2/, and in 1989, tests were carried out on a section of high-density concrete core from Pickering NGS A/3/. The CIC concrete had different mix proportions and physical properties from the concrete evaluated here and the thermal properties would therefore be expected to vary. The physical properties of the core section from Pickering NGS A tested in 1989 were not determined.

The specimens tested for the coefficient of linear thermal expansion consisted of sections of concrete cores fitted with gauge points at the ends. The testing was carried out in a SSD condition, and length measurements were obtained at three temperatures, 3°, 23° and 62°C. Three readings were obtained at each temperature to ensure that the specimen had stabilized.

The coefficient of linear thermal expansion of the three specimens, tested in a SSD condition, ranged from 9.6×10^{-6} to $10.1 \times 10^{-6}/^{\circ}\text{C}$. As with normal density concrete, these values would be expected to be higher for partially saturated concrete. An average value of $11.3 \times 10^{-6}/^{\circ}\text{C}$ was obtained from tests carried out on the CIC high-density concrete prisms sealed in bituthene 24 hours after casting/2/.

The thermal diffusivity of the three specimens (SSD) tested ranged from 613×10^{-9} to $634 \times 10^{-9} \text{ m}^2/\text{s}$ and averaged $620 \times 10^{-9} \text{ m}^2/\text{s}$. Two series of tests were conducted on each specimen. Testing carried out on high-density concrete produced for the CIC program gave an average value of $910 \times 10^{-9} \text{ m}^2/\text{s}/3/$. The section of concrete core from Pickering NGS A tested in 1989 had a value of $589 \times 10^{-9} \text{ m}^2/\text{s}/3/$.

The specific heat of the concrete ranged from 843 to 883 J/kg · °C and averaged 861 J/kg · °C. The testing was carried out using cold (2°C) and hot (50°C) water baths. Testing conducted previously gave values of 838 J/kg · °C for the high-density concrete for the CIC program/2/ and 882 J/kg · °C for the high-density concrete core obtained from Pickering NGS A in 1989/3/.

Using the US Corps of Engineers test procedure, the thermal conductivity of the specimens was calculated as a product of the density, thermal diffusivity and specific heat of the concrete. The thermal conductivity ranged from 1.86 to 2.03 W/°C · m and averaged 1.93 W/°C · m. Testing conducted previously produced values of 2.77 W/°C · m for the CIC high-density concrete/2/ and 1.91 W/°C · m for the concrete core from Pickering NGS A/3/. All of these values were determined on SSD concrete.

The transient thermal probe was developed to measure the thermal resistivity and conductivity of soils. The method consists of inserting a thin cylindrical probe, containing a heating element and a thermocouple, longitudinally into the centre of a cylindrical specimen. Constant power is applied to the heating element and the temperature-time data plot used to determine the thermal properties of the specimen. This method was used previously with the section of a core obtained from Pickering NGS A and tested in 1989/3/.

A test specimen was prepared by drilling a 10 mm diameter by 155 mm deep vertical hole longitudinally into the centre of a section of core (Section 3W3). The thermal probe was then grouted into the hole using high-density aggregate grout. Two measurements were made at each of three moisture conditions. The moisture condition and the average values of two measurements are given below.

Moisture Condition	Thermal Conductivity
0% saturated*	1.49 W/°C · m
37% saturated	1.71 W/°C · m
100% saturated (saturated surface dry)	2.19 W/°C · m

* for this test, 60°C was used for mass stabilization instead of 100°C as reported earlier.

As expected, the results vary with moisture condition of the specimen. The conductivity obtained in 1989, on a section of core using a thermal probe, was 1.88 W/°C · m. This core section had been stored at approximately 35% relative humidity for one month prior to testing.

The thermal conductivity of the saturated concrete tested using the two procedures varied from 1.93 W/°C · m (US Corp of Engineers Procedure) to 2.19 W/°C · m (Transient Thermal Probe). It should be noted that the application of the transient thermal probe for the testing of concrete is relatively new and the correlation between this method and the US Corps of Engineers test procedure is not known.

3.3 Chemical Composition

At the request of Mr. C.M. Alexander, the Civil Research Department forwarded samples of high-density concrete from Unit 3 to the Chemical Research Department for chemical analysis. In particular, the concentration of zinc, iron, calcium, aluminum, potassium, titanium and lithium were of interest. The results of the analysis are given in Appendix B.

Samples of the concrete were analyzed qualitatively using X-ray fluorescence and X-ray diffraction techniques. The main constituents of the concrete were determined to be iron and titanium. The main compounds identified were iron and titanium oxides, which are the mineralogical composition of ilmenite and hematite that constitute the aggregates used in the concrete. The white deposits associated with cracks in the Unit 3 concrete were also analysed. They were found to be composed primarily of calcium. Although calcium is a component of the cement, the significance of calcium deposits in these cracks is not understood at the present time.

4.0 DISCUSSION

It is evident from the test results that the concrete from the Units 1 and 3 reactor vaults differs significantly in physical properties. The results obtained from the Unit 3 cores were similar to those obtained as part of the quality assurance program carried out during construction; however, the values of results obtained from the Unit 1 cores were significantly higher. Also, the cracking in the mortar of the Unit 3 cores observed after immersion in water was not observed in the cores from Unit 1. A review of the inspectors concrete reports prepared during construction did not indicate any variation in the concrete mix proportions. A conclusive explanation for the differences in the properties of the concrete from the two units cannot be made; however, it is possible that there may have been variations in the properties of the aggregates or in the curing applied to the concrete during construction.

Specimens were selected at various locations through the thickness of the wall in order to determine whether any changes in the physical properties of the concrete had occurred due to the operating environment of the reactor. The sections of the cores from the inside wall of the reactor vault, which would be expected to exhibit the most significant change in physical properties if any had occurred, were either not received or were not suitable for testing. In some of the specimens tested, a slight increase in strength and modulus of elasticity was noted with distance from the reactor; however, this could be a result of variations within the test procedure.

The thermal properties of the concrete generally varied from the values obtained previously on high-density concrete tested as part of the concrete integrated cask (CIC) program. Some variation is expected because the concrete for the CIC program had different mix proportions and physical properties from the Pickering NGS concrete, and the coefficient of thermal expansion was determined under a different moisture condition. The thermal conductivity of the core section obtained from Pickering NGS A in 1989 was similar to the test results obtained here. The thermal conductivity determined using the transient thermal probe produced results that varied with moisture condition of the specimen.

Numerical values of the thermal properties of the concrete, excluding the coefficient of thermal expansion, tended to increase with distance from the reactor. Whether this is significant or it is within experimental error is unknown.

It was understood that the purpose of the chemical analysis was to compare the chemical composition of the concrete with that of debris analysed previously by AECL Research. No evaluation of the data in Appendix B was carried out as part of the program reported here. When reviewing the results of the analysis, it should be noted that the mobility of the various elements comprising the concrete is affected by many factors. Therefore, the elemental composition of the debris from the reactor vault, if originating from the concrete, would not necessarily have a similar chemical composition to that of the concrete.

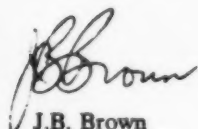
5.0 SUMMARY AND RECOMMENDATIONS

- 1) Physical properties of high-density concrete core sections from the Pickering NGS A Units 1 and 3 reactor vaults were determined. The concrete from the Unit 1 reactor vault had significantly higher density, ultrasonic pulse velocity, compressive strength and modulus of elasticity than those of the Unit 3 concrete. The cause of this could not be determined.
- 2) White deposits observed along cracks in the concrete after immersion for a few months could not be explained. These cracks were only observed in the concrete from Unit 3. It is therefore recommended that an attempt be made to understand the cause and significance of these cracks.
- 3) Some variation was noted in the physical properties of the concrete with location in the wall, but it could not be determined whether this was due to the service environment of the reactor vault or it was within the variability of the test procedure. It should be noted that the sections of cores closest to the inside

surface of the reactor vault, which would be expected to exhibit the most significant changes as a result of exposure to the reactor environment, were either not received or were not suitable for testing. In the future, an attempt should be made to obtain suitable specimens from this location.

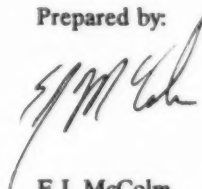
- 4) Thermal properties of the concrete from the Unit 3 reactor vault were determined. The thermal conductivity as determined using the transient thermal probe varied with moisture condition of the concrete. The thermal properties of the concrete in situ will therefore vary with the moisture content of the concrete. Because the transient thermal probe method for determining the thermal conductivity of concrete is relatively quick and simple to perform, it is recommended that work be carried out to determine the correlation between this method and the US Corp of Engineers test procedure.
- 5) It is recommended that an in-depth review be carried out of the service environment of the shielding wall (ie, temperature, moisture, radiation, etc.) in order to better understand the reported differences in the properties of the high-density concrete. This may require discussion with the operation and design personnel, review of literature, further testing of cores already obtained and testing of laboratory prepared specimens.

Approved by:



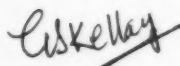
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- 1) Research Division Report S89-40-H, "Concrete Integrated Container (CIC) Program: Casting A 1/4-Scale Model", January 24, 1990.
- 2) Research Division Report 85-234-H, "Concrete Integrated Cask Program, Thermal Properties of High Density Concrete", September 10, 1985.
- 3) Research Division Report S89-20-K, "Pickering NGS A, Thermal Conductivity of High-Density Concrete", July 21, 1989.

TABLE 1
PICKERING NGS A UNIT 1
LABORATORY TESTING OF CONCRETE CORES
PHYSICAL PROPERTIES

Specimen ID	Density SSD (kg/m ³)	Absorption (%)		Ultrasonic Pulse Velocity (m/s)	Compressive Strength (MPa)	Modulus of Elasticity (GPa)
		After Immersion	After Boil			
Core W						
1W1	3863	2.9	3.0	-	-	-
1W2	3859	3.0	3.1	-	-	-
1W3	3903	-	-	4760	49.8	53.7
1W4	3904	-	-	4760	47.1	-
1W5	3898	-	-	4660	54.0	51.9
1W6	3933	-	-	4760	48.1	-
1W7	3929	-	-	4660	50.8	50.9
Core E						
1E1	3881	-	-	4440	55.3	50.4
1E2	3920	-	-	4610	53.0	-
1E3	3969	-	-	4930	47.0	52.7
1E4	3910	2.8	2.8	-	-	-
1E5	3886	2.8	2.8	-	-	-
Construction test results	3795	-	-	-	28-day strength 33.8	-

Notes:

- 1) Density: The density of saturated surface dry (SSD) concrete was determined.
- 2) Absorption: The absorption after immersion and after boiling was determined as per test procedure ASTM C 642.
- 3) Ultrasonic Pulse Velocity: The ultrasonic pulse velocity was measured following test procedure ASTM C 597 and was measured longitudinally through the specimens prior to testing for compressive strength.
- 4) Compressive Strength: Test procedure CAN/CSA-A23.2-14C was followed to determine the compressive strength. The specimens were tested at a 50% saturation condition to reflect the moisture condition of the in situ concrete. For this test, 100% saturation was obtained by immersion in water at 23°C until mass equilibrium was obtained. The as-received moisture conditions of specimens were as follows: 1W1 26%, 1W2 46%, 1E4 46%, 1E5 46%. The specimens for compressive strength and modulus of elasticity were conditioned prior to testing by allowing saturated specimens to come into mass equilibrium at 50% relative humidity and 23°C.
- 5) Modulus of Elasticity: The modulus of elasticity was determined as per test procedure ASTM C 469. See Note 4 for the moisture condition of the specimens.

TABLE 2
PICKERING NGS A UNIT 3
LABORATORY TESTING OF CONCRETE CORES
PHYSICAL PROPERTIES

Specimen ID	Density SSD (kg/m ³)	Absorption After Immersion (%)	Ultrasonic Pulse Velocity (m/s)	Compressive Strength (MPa)	Modulus of Elasticity (GPa)
Core W					
3W1	3623	-	4190	34.3	45.8
3W2	3664	-	4280	34.2	-
3W4A	3684	3.7	-	-	-
3W5	3700	-	4150	28.8	-
3W6	3734	-	4180	30.3	41.4
Core E					
3E1A	3662	3.9	-	-	-
3E2	3651	-	4300	35.2	-
3E3	3575	-	4330	34.2	43.8
3E5A	3684	4.0	-	-	-
Construction Test Results	3764	-	-	28-day strength 34.5	-

Notes:

- 1) Density: The density of saturated surface dry (SSD) concrete was determined.
- 2) Absorption: The absorption after immersion was determined as per test procedure ASTM C 642.
- 3) Ultrasonic Pulse Velocity: The ultrasonic pulse velocity was measured following test procedure ASTM C 597 and was measured longitudinally through the specimens prior to testing for compressive strength.
- 4) Compressive Strength: The compressive strength of SSD specimens was determined as per test procedure CAN/CSA-A23.2-14C.
- 5) Modulus of Elasticity: The modulus of elasticity of SSD specimens was determined as per test procedure ASTM C 469.

TABLE 3
PICKERING NGS A UNIT 3
LABORATORY TESTING OF CONCRETE CORES
THERMAL PROPERTIES

Specimen ID	Density SSD (kg/m ³)	Coefficient of Linear Thermal Expansion SSD (Strain/°C)	Thermal Diffusivity SSD (m ² /s)	Specific Heat (J/kg · °C)	Thermal Conductivity W/ (W/°C · m)
Core W 3W4	3664	9.62×10^{-6}	613×10^{-9}	843	1.89
Core E 3E1 3E5	3627 3532	9.71×10^{-6} 10.08×10^{-6}	634×10^{-9} 614×10^{-9}	883 857	2.03 1.86

Notes:

- 1) Density: The density of saturated surface dry (SSD) concrete was determined.
- 2) Coefficient of Linear Thermal Expansion: Specimens were tested in a SSD condition following US Corps of Engineers test procedure CRD-C 39-81.
- 3) Thermal Diffusivity: Specimens were tested in a SSD condition following US Corps of Engineers test procedure CRD-C 36-73.
- 4) Specific Heat: Specimens were tested in a SSD condition following US Corps of Engineers test procedure CRD-C 124-73 (Modified).
- 5) Thermal Conductivity: The thermal conductivity was calculated from the density, thermal diffusivity and specific heat following US Corps of Engineers test procedure CRD-C 44-63.

APPENDIX A
PICKERING NGS A
REACTOR VAULTS
CONCRETE CORE LOG

**PICKERING NGS A UNIT 1
REACTOR VAULT
CONCRETE CORE LOG**

Core Section	Location From - To (mm)	Remarks
Core 1W		
1W1	0 - 110	Core diameter 144 mm. Core section 1W1A was obtained from overcoring Section 1W1.
1W1A	0 - 110	
1W2	110 - 330	
1W3	330 - 630	
1W4	630 - 935	
1W5	935 - 1235	
1W6	1235 - 1515	
1W7	1515 - 1830	
Core 1E		
1E1	0 - 310	Core sections 1E1 to 1E4 are 144 mm diameter.
1E2	310 - 610	
1E3	610 - 895	Core sections 1E5 to 1E8 are 119 mm diameter.
1E4	895 - 1015	
1E5	1015 - 1205	Cross-section of Core Sections 1E5 to 1E8 is irregular.
1E6	1205 - 1510	
1E7	1510 - 1810	
1E8	1810 - 2130	

- The cores were drilled horizontally by construction personnel from the high-density concrete plug in the south wall of the Unit 1 reactor vault at Elevation 278.5' (Figure A1). The reported thickness of the wall at this location is 2130 mm. The cores sections were numbered starting from the outside face of the reactor vault wall.
- The cores were either 119 or 144 mm in diameter and consisted of high-density concrete.
- Core Sections 1E5 to 1E8 did not have a circular cross-section, probably due to over-coring caused by construction activities.
- The distribution of aggregates in the concrete was classified as good.
- The nominal maximum size of the coarse aggregate was 15 mm.
- The concrete appeared to be in good condition.
- The core breaks occurred through the aggregate.

**PICKERING NGS A UNIT 3
REACTOR VAULT
CONCRETE CORE LOG**

Core Section	Location From - To (mm)	Remarks
Core W		
W-1	0 - 300	Core diameter 144 mm.
W-2	300 - 620	
W-3	620 - 940	
W-4	940 - 1210	
W-5	1210 - 1520	
W-6	1520 - 1830	
Core E		
E-1	0 - 270	Core diameter 144 mm.
E-2	270 - 570	
E-3	570 - 880	
E-4	880 - 1170	Cross-section of Core Section E6 is irregular.
E-5	1170 - 1470	
E-6	1470 - 1780	

- The cores were drilled horizontally by construction personnel from the high-density concrete plug in the south wall of the Unit 3 reactor vault at Elevation 278.5' (Figure A2). The reported thickness of the wall at this location is 2130 mm. The cores sections were numbered starting from the outside face of the reactor vault wall.
- The cores were 144 mm in diameter and consisted of high-density concrete.
- The distribution of the aggregates in the concrete was classified as good.
- The nominal maximum size of the coarse aggregate was 15 mm.
- The concrete appeared to be in good condition.
- The core breaks occurred through the aggregates.
- After immersing selected core sections in water for approximately two months, fine cracks with associated white deposits were observed in the mortar.

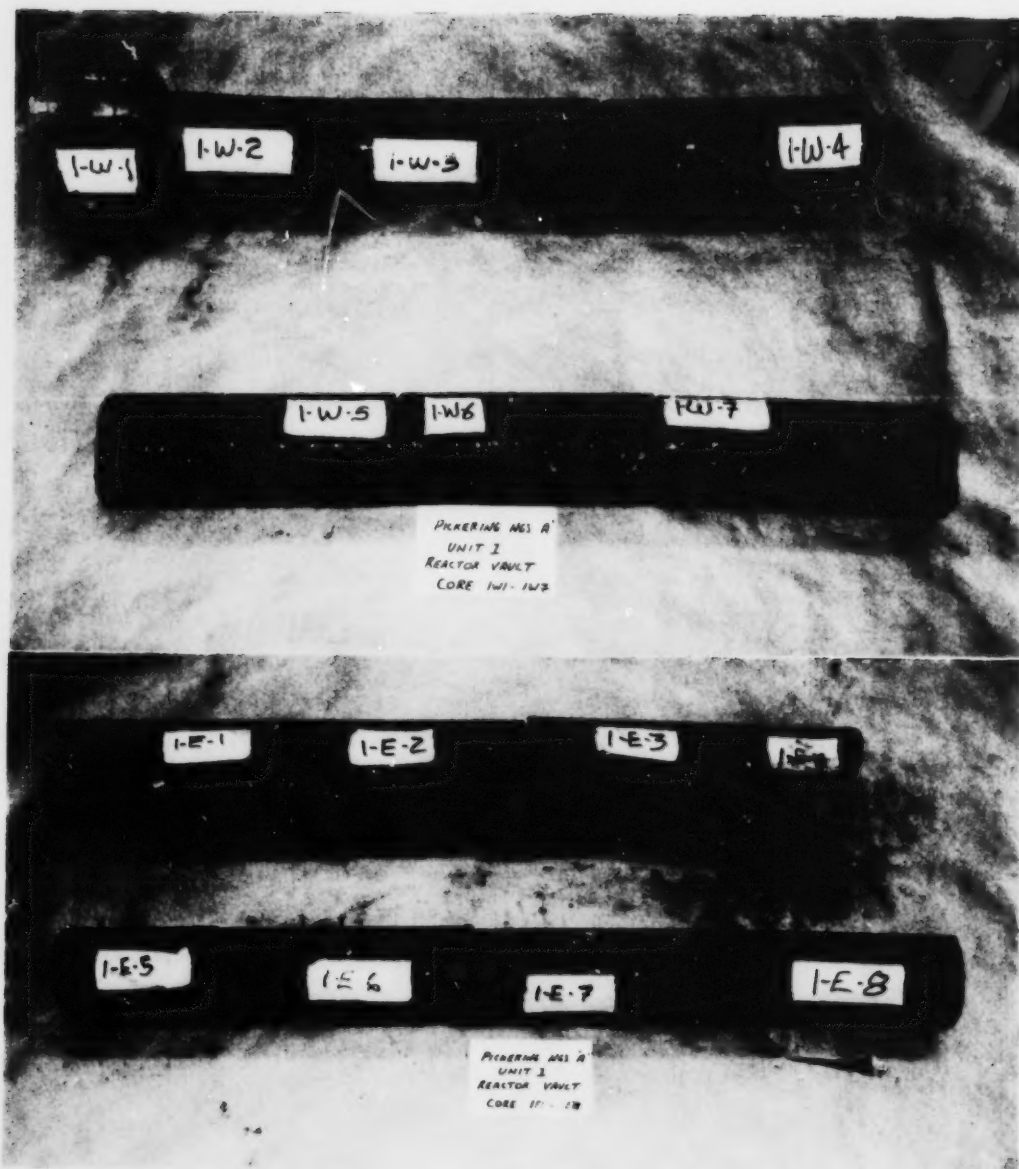


Figure A1: The two cores drilled from the Pickering NGS A Unit 1 reactor vault wall were identified as Cores 1W and 1E. The core sections have been identified from 1 to 7 or 1 to 8 extending from the outside face of the vault wall towards the inside.

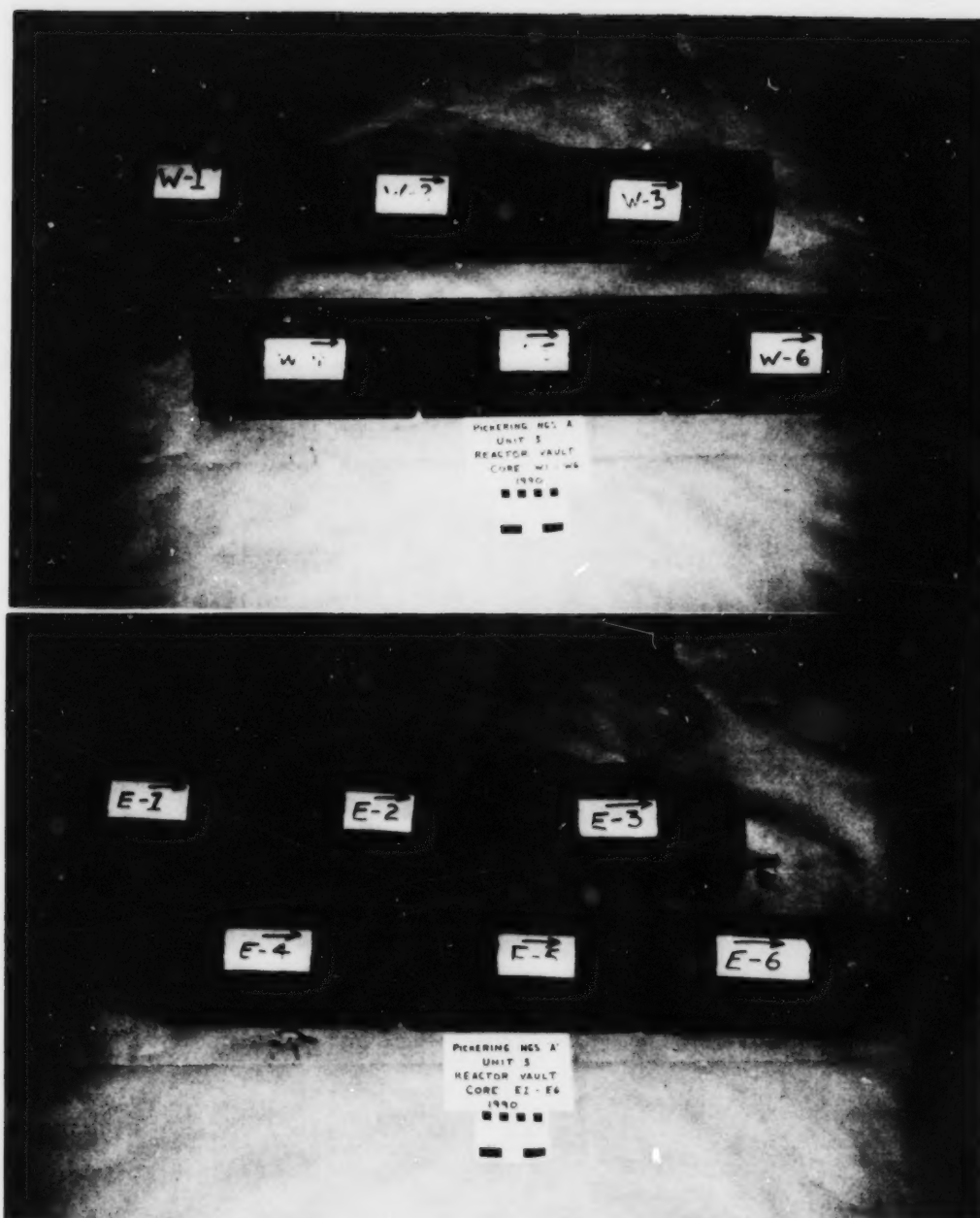


Figure A2: The two cores drilled from the Pickering NGS A Unit 3 reactor vault wall were identified as Cores 3W and 3E. The core sections have been identified from 1 to 6 extending from the outside face of the vault wall towards the inside.

APPENDIX B
PICKERING NGS A
REACTOR VAULTS
CHEMICAL COMPOSITION OF CONCRETE

Research Division
800 Kipling Avenue, Toronto, Ontario, Canada M8Z 5S4

Information Copy - original sent to: Dr. John Krassnai

Mr. Edward J. McColm
Engineer
Civil Research Dept
KR161
7185

6 May 91

836.6

Report of Chemical Analysis Number CE-91-1914 -K

Sample Description: 3 SAMPLES OF HIGH DENSITY CONCRETE FROM PNGS-U3
These samples were submitted from MATERIALS CHEMISTRY
These samples were received in our laboratory on 26 Mar 91.
Note: 1 ELEMENTAL COMPOSITION BY XRF. ID WHITE DEPOSIT
EVIDENT IN 3-E1 BY XRF FIRST. SAMPLES NOT RADIOACTIVE

Sample Number: 1 Sample Name: 3-W4

Qualitative X-Ray Fluorescence Analysis

A search is made for all elements with Atomic No.
greater than 11.

N.B. Qualitative analyses are primarily used for the
identification of the elements present. Reported relative
amounts of these elements are estimates only, based on
the judgement of the analyst.

XRF Results

The main constituent(s) is (are); Iron & Titanium.

The other elements detected are listed below in the
order of their apparent relative abundance;

Calcium
Silicon
Sulphur
Aluminium
Manganese



Strontium
Chromium
Zinc
Zirconium
Potassium
Nickel
Copper
Magnesium
Niobium
Barium

Qualitative X-Ray Diffraction Analysis for Crystalline
Phases (Compounds).

IRD Results

Crystalline Phase(s) Identified

Iron Titanium Oxide / Ilmenite, = FeTiO_3
Iron Oxide / Hematite, = Fe_2O_3

~~Sample Number: 2 Sample Name: 3-El~~

Analysis of White Fracture Deposit

Qualitative X-Ray Fluorescence Analysis

A search is made for all elements with Atomic No.
greater than 11.

N.B. Qualitative analyses are primarily used for the
Identification of the elements present. Reported relative
amounts of these elements are estimates only, based on
the judgement of the analyst.

IRF Results

The main constituent(s) is (are); Calcium & Iron

The other elements detected are listed below in the
order of their apparent relative abundance;

Silicon
Titanium
Copper
Potassium
Chlorine

Analysis of Blended Sample

Qualitative X-Ray Diffraction Analysis for Crystalline
Phases (Compounds).

IRD Results

Crystalline Phase(s) Identified

Iron Titanium Oxide / Ilmenite, = FeTiO_3

3

Iron Oxide / Hematite, = Fe_2O_3

2 3

Crystalline Phase Possibly Present

Calcium Hydroxide / Portlandite, = Ca(OH)_2

2

Analysis of White Deposit

Qualitative X-Ray Diffraction Analysis for Crystalline
Phases (Compounds).

IRD Results

Crystalline Phase(s) Identified

None. The sample appears to be largely micro-crystalline
or amorphous.

~~Sample Number: 23 Sample Name: 3-E5 - Concrete~~

*Qualitative X-Ray Diffraction Analysis for Crystalline
Phases (Compounds).*

IRD Results

Crystalline Phase(s) Identified

Iron Titanium Oxide / Ilmenite, = FeTiO_3

3

Iron Oxide / Hematite, = Fe_2O_3

2 3

The charge to account number 42-133

is \$ 720

This analysis was carried out by Brian Pattenden

6054

____ Original Signed by ____

Michael Booth
Supervising Chemist-Analytical Services
Chemical Research Department
Phone 122 + 6734, FAX (416) 231-2877

Copies to: Mr. Edward J. McColm

Research Division
800 Kipling Avenue, Toronto, Ontario, Canada M8Z 5S4

Memorandum

Dr. John Krassnai
Chemist
Material Chemistry Section
KR-220
122+6260

5 Sep 91

836.6

Report of Chemical Analysis Number CE-91-4302 -K

Sample Description: HIGH DENSITY (ILMERITE) CONCRETE FROM PNGS U/3

These samples were submitted from MATERIALS CHEMISTRY

These samples were received in our laboratory on 15 Jul 91.

**Note: IT WILL BE REQUIRED TO DIGEST CONCRETE COMPLETELY
INCLUDING $FeTiO_3$ AGGREGATE.**

No	Sample Name	Analyte	Result	Units
1	CONCRETE SAMPLE	Aluminum by ICP	6300.	ppm
		Calcium by ICP	39100.	ppm
		Chromium by ICP	0.07	%
		Copper by ICP	<0.01	%
		Iron by ICP	364000.	ppm
		Potassium by ICP	300.	ppm
		Lithium by ICP	<100.	ppm
		Manganese by ICP	0.09	%
		Silicon by ICP	1.6	%
		Strontium by ICP	0.01	%
		Titanium by ICP	177000.	ppm
		Zinc by ICP	140.	ppm
		Sulfur by Leco	0.31	%

Energy from Ideas



The charge to account number 42-133
This analysis was carried out by Walter Shapka

is \$ 600

Michael Booth
Supervising Chemist-Analytical Services
Chemical Research Department
Phone 122 + 6734, FAX (416) 231-2877

Copies to: Mr. Edward J. McColm